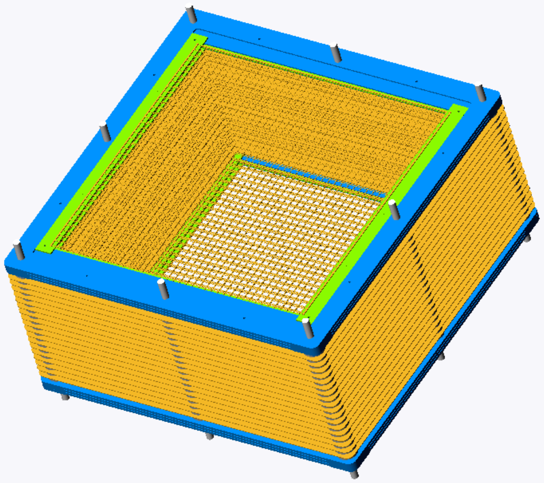
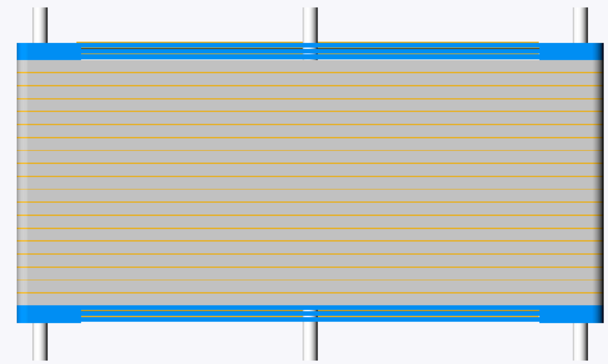
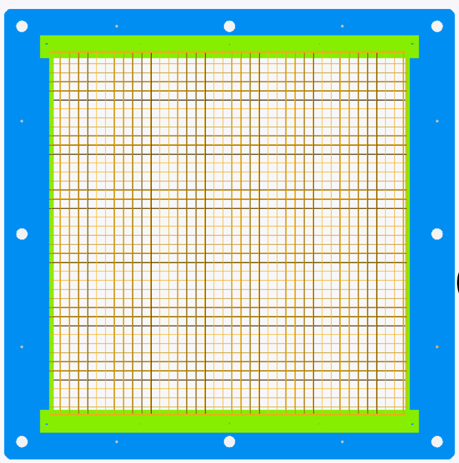
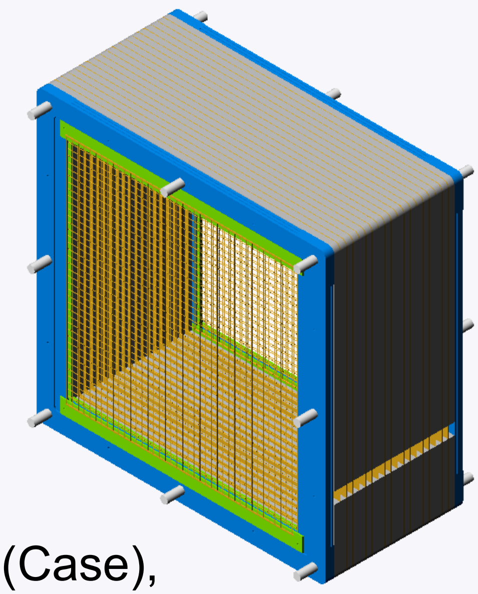




Beta Cage

A Screener of Ultra-Low-Level Radioactive Surface Contamination





Richard Schnee

Case Western Reserve University

In collaboration with

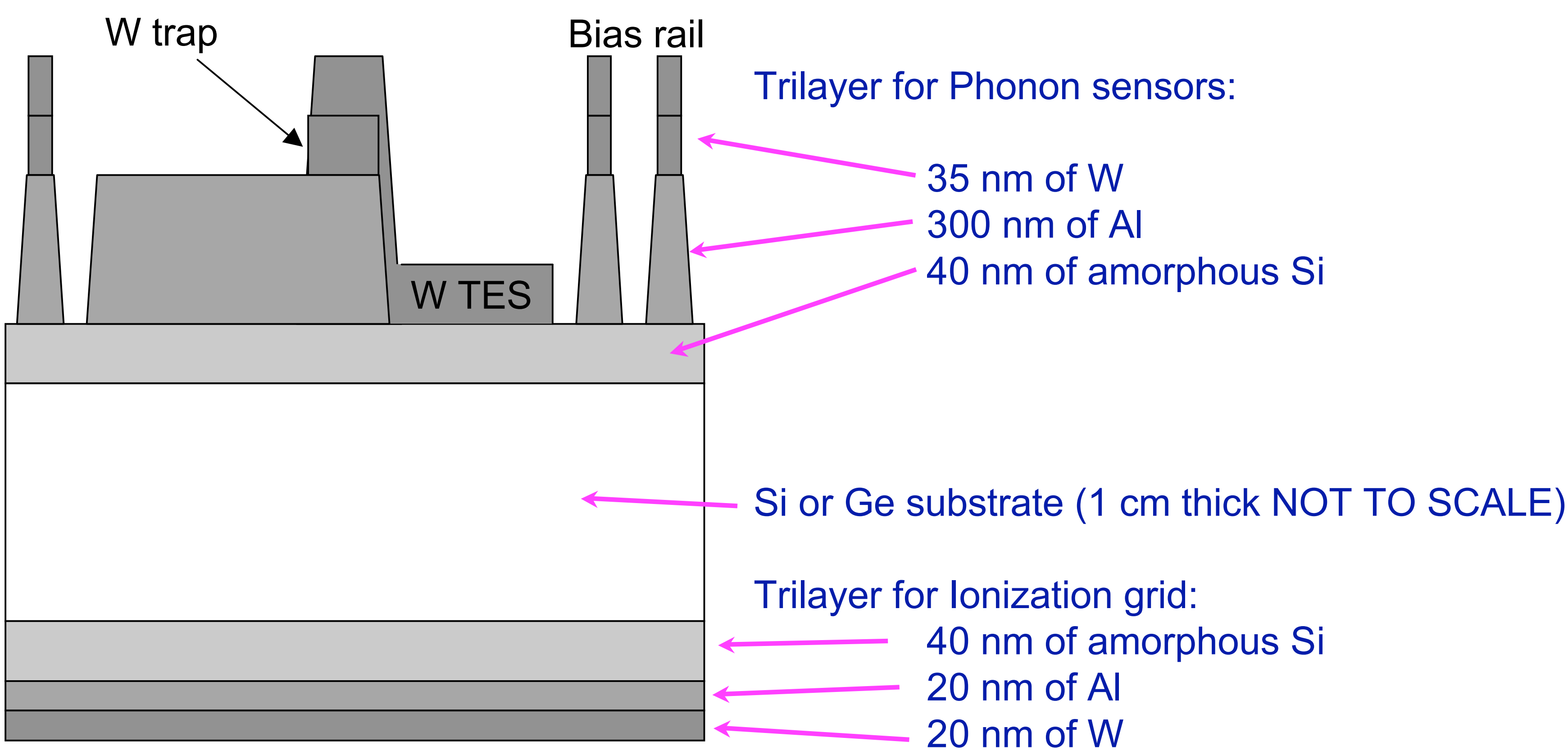
Dan Akerib, Darren Grant, Kristin Poinar, Tom Shutt (Case),

Sunil Golwala, Zeesh Ahmed (Caltech)

(and with work from others who have moved on)

Original Motivation: CDMS

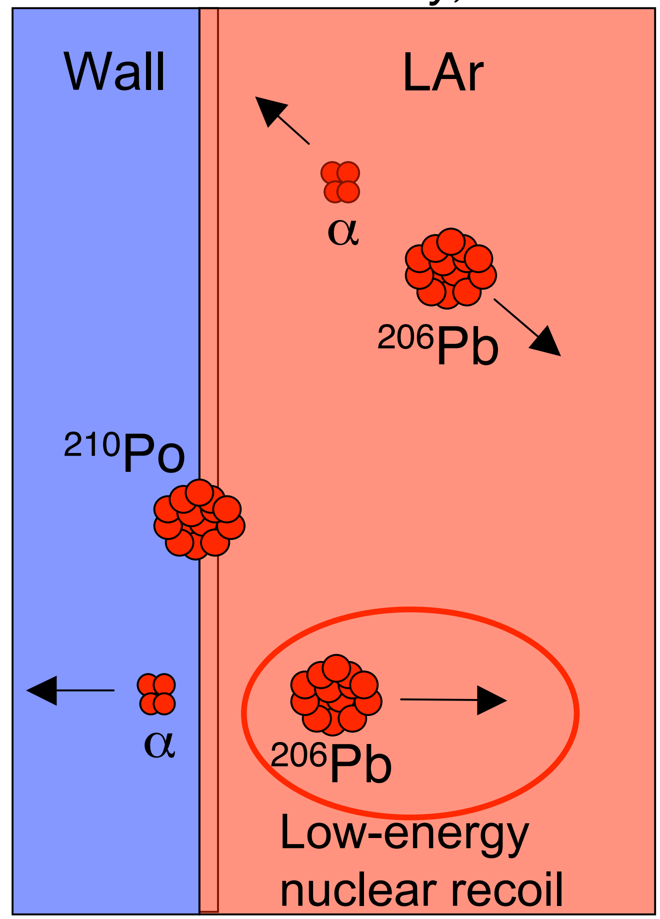
- CDMS experiment limited by beta contaminants (especially ^{210}Pb from radon) on surface or in thin films of detectors
  - Projected 150 kg SuperCDMS experiment could be background free if beta contamination kept < 6 m^{-2} day^{-1} in WIMP energy region

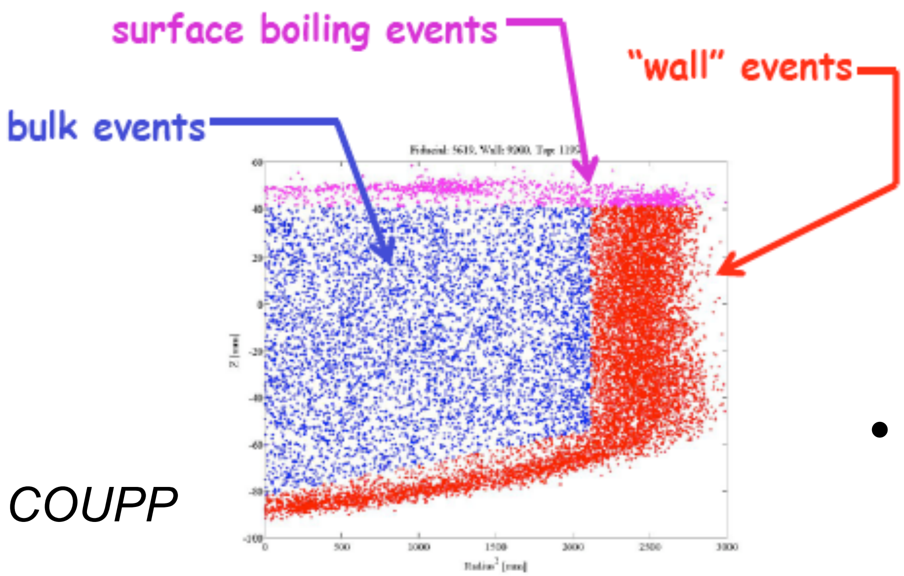


Additional Motivation

- EDELWEISS similarly sensitive to beta contamination on surfaces
- Alphas on surfaces
  - Generic problem for experiments with liquid targets (DEAP/CLEAN, WARP,…)
  - Dominant background is recoiling nuclei from alpha emission (especially ^{210}Po from radon) on surface
  - Same source reduces livetime in COUPP

M. Boulay, Queen's





COUPP

- Carbon or tritium dating, etc.

Need for Alpha/Beta Screening Facility

- Better sensitivity to some α-emitting or β-emitting isotopes than Ge γ detectors or other techniques such as ICP-MS
- Some beta-emitting isotopes can be probed only by their beta or alpha emission

Method	Detectable Long-lived Beta-emitting Isotopes
ICP-MS (1 ppb)	^{40}K ^{48}Ca ^{50}V ^{87}Rb ^{92}Nb ^{98}Tc ^{113}Cd ^{115}In ^{123}Te ^{138}La ^{176}Lu ^{182}Hf ^{232}Th ^{235}U ^{238}U ^{236}Np ^{250}Cm
ICP-MS (1 ppt)	^{10}Be ^{36}Cl ^{60}Fe ^{79}Se ^{93}Zr ^{94}Nb ^{97}Tc ^{99}Tc ^{107}Pd ^{126}Sn ^{129}I ^{135}Cs ^{137}La ^{154}Eu ^{158}Tb ^{166m}Ho ^{208}Bi ^{208}Po ^{209}Po ^{252}Es
γ	^{40}K ^{50}V ^{60}Fe ^{60}Co ^{93}Zr ^{92}Nb ^{94}Nb ^{93}Mo ^{98}Tc ^{99}Tc ^{101}Rh ^{101m}Rh ^{102m}Rh ^{109}Cd ^{121m}Sn ^{126}Sn ^{125}Sb ^{129}I ^{134}Cs ^{137}Cs ^{133}Ba ^{138}La ^{145}Pm ^{146}Pm ^{150}Eu ^{152}Eu ^{154}Eu ^{155}Eu ^{157}Tb ^{158}Tb ^{166m}Ho ^{173}Lu ^{174}Lu ^{176}Lu ^{172}Hf ^{179}Ta ^{207}Bi ^{208}Bi ^{232}Th ^{235}U ^{238}U ^{236}Np ^{241}Pu
α	^{210}Pb ^{208}Po ^{209}Po ^{228}Ra ^{227}Ac ^{232}Th ^{235}U ^{238}U ^{236}Np ^{241}Pu ^{250}Cm ^{252}Es
β only	^{3}H ^{14}C ^{32}Si ^{63}Ni ^{90}Sr ^{106}Ru ^{113m}Cd ^{147}Pm ^{151}Sm ^{171}Tm ^{194}Os ^{204}Tl ^{10}**Be** ^{36}**Cl** ^{79}**Se** ^{97}**Tc** ^{107}**Pd** ^{135}**Cs** ^{137}**La** ^{154}**Eu** ^{209}**Po**

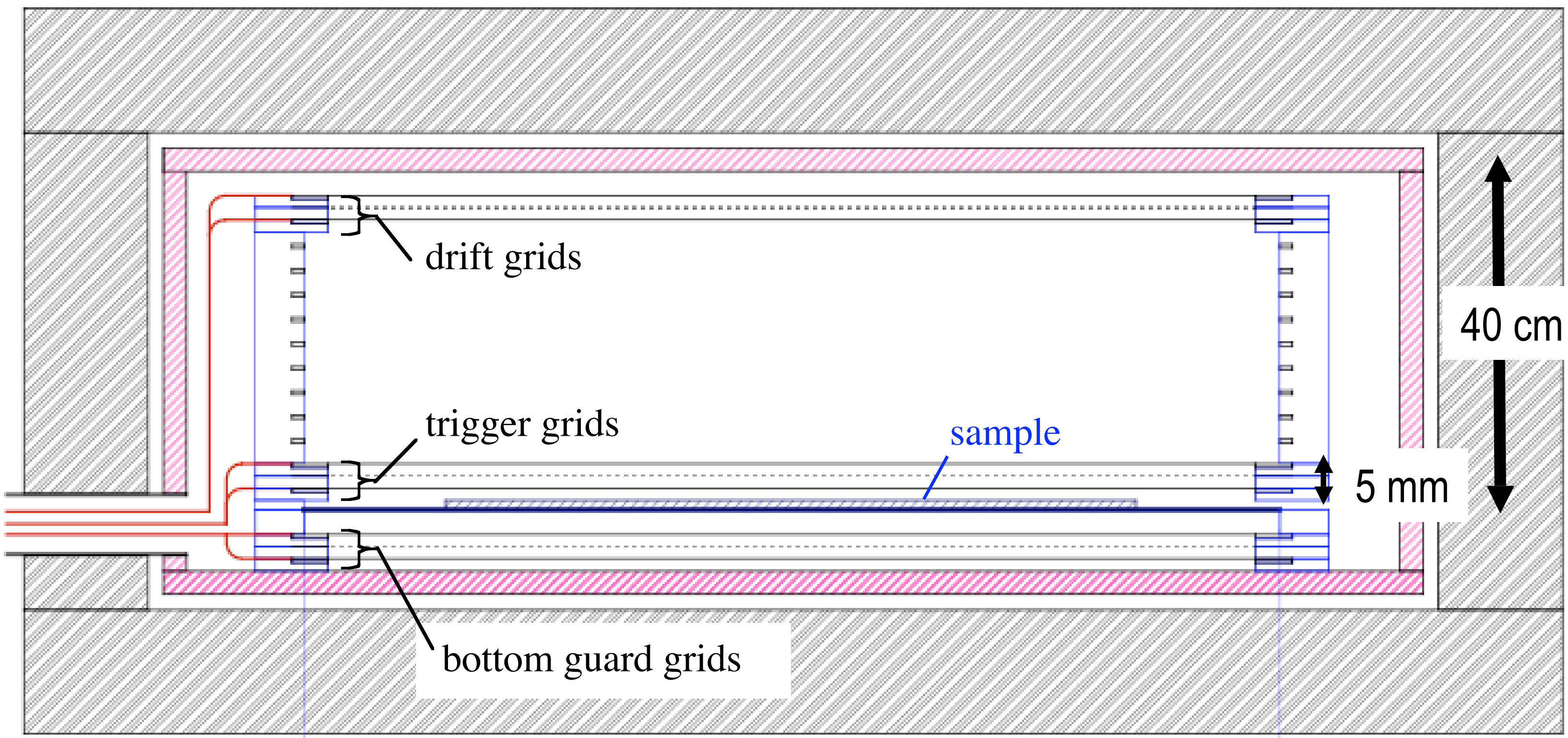
H. Nelson, UCSB

Basic Design Principles

- Deploy sample in detector (don't use window)
- Backgrounds are proportional to mass of detector
  - Ultraclean materials to minimize internal contamination
  - Underground, shielded apparatus to minimize external backgrounds
- Deploy minimum material needed to stop βs.
  - Gas is best method to achieve this low mass
  - 150 keV e^- ≈ 30 cm Ne (1 atm)
  - Can identify betas with <200 keV endpoint with 40 cm height
  - Could Use Xe (1 atm) for higher-energy betas (range ~7x less)
  - 10 MeV alpha range is only 20 cm in Ne
- Maximize counting statistics
  - Large surface area (horizontal dimension) ~1 m^2
- Guard region to reject events emitted from outside chamber
- Expect ~100x more sensitive than existing instruments

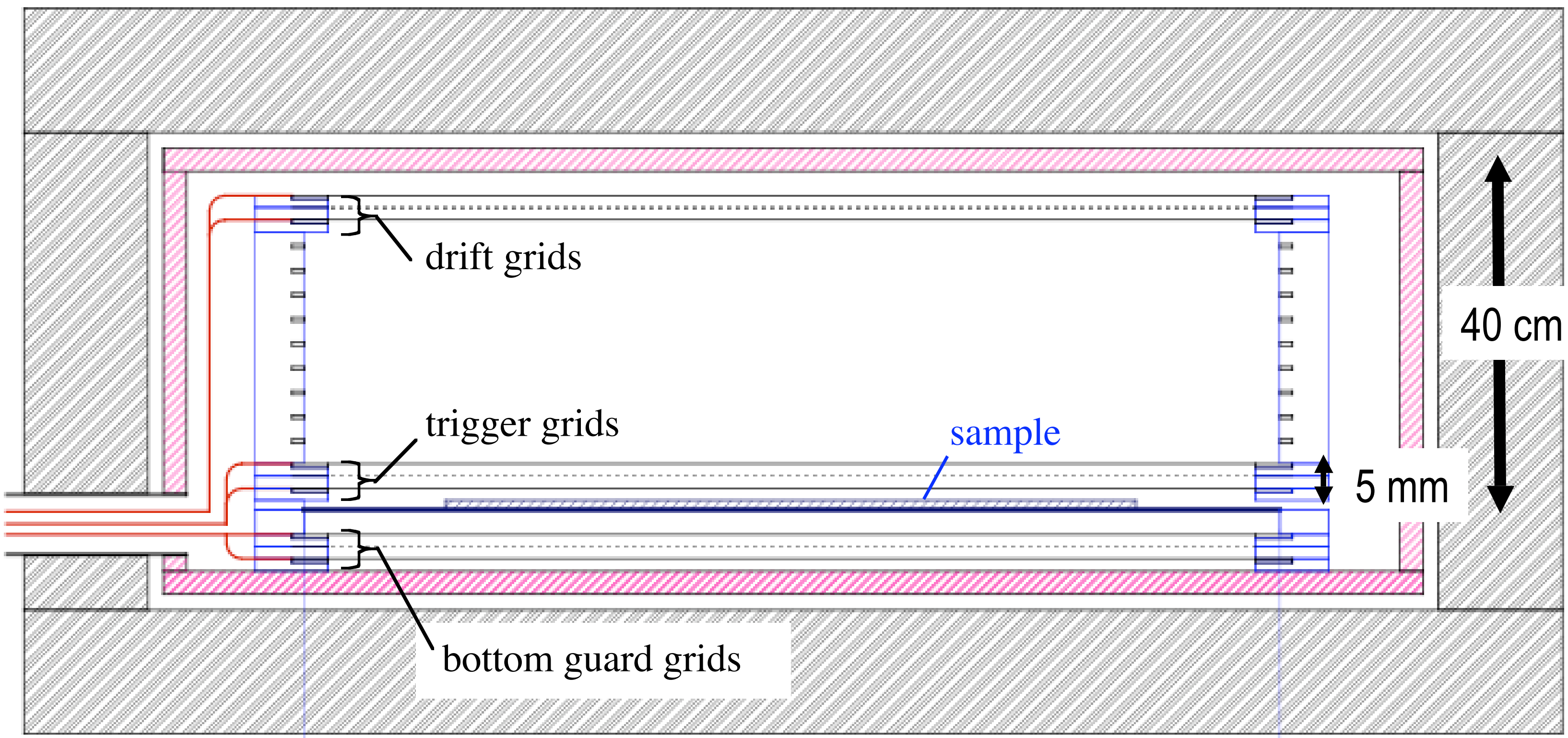
BetaCage

- Multiwire proportional counter
- Wires provide minimum surface area for emissions
  - 25 µm Ø, 1/2 cm spacing - 0.5% coverage
- Crossed grids could yield ~mm xy position information
  - Identify source position of contamination



BetaCage

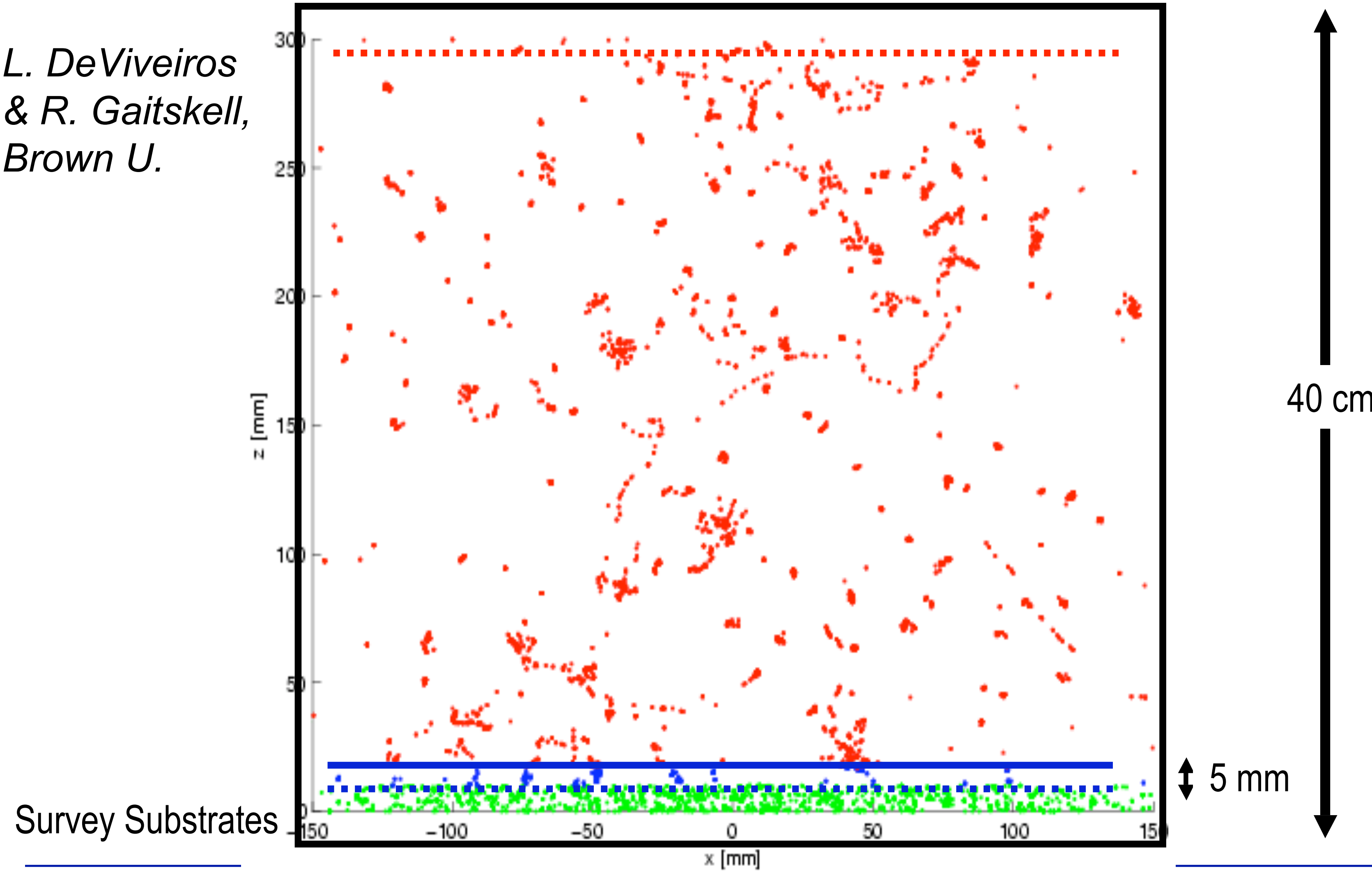
- Reject background interactions in bulk of gas by creating narrow (5 mm) “trigger region” near samples
  - Most gamma interactions in gas don’t cause trigger
  - Reduces backgrounds in gas to 15% of unrejectable total due to gamma interactions in sample that eject electrons into trigger region (these look exactly like beta emission)



Results of Monte Carlo Simulation

- Reject most gamma interactions in gas

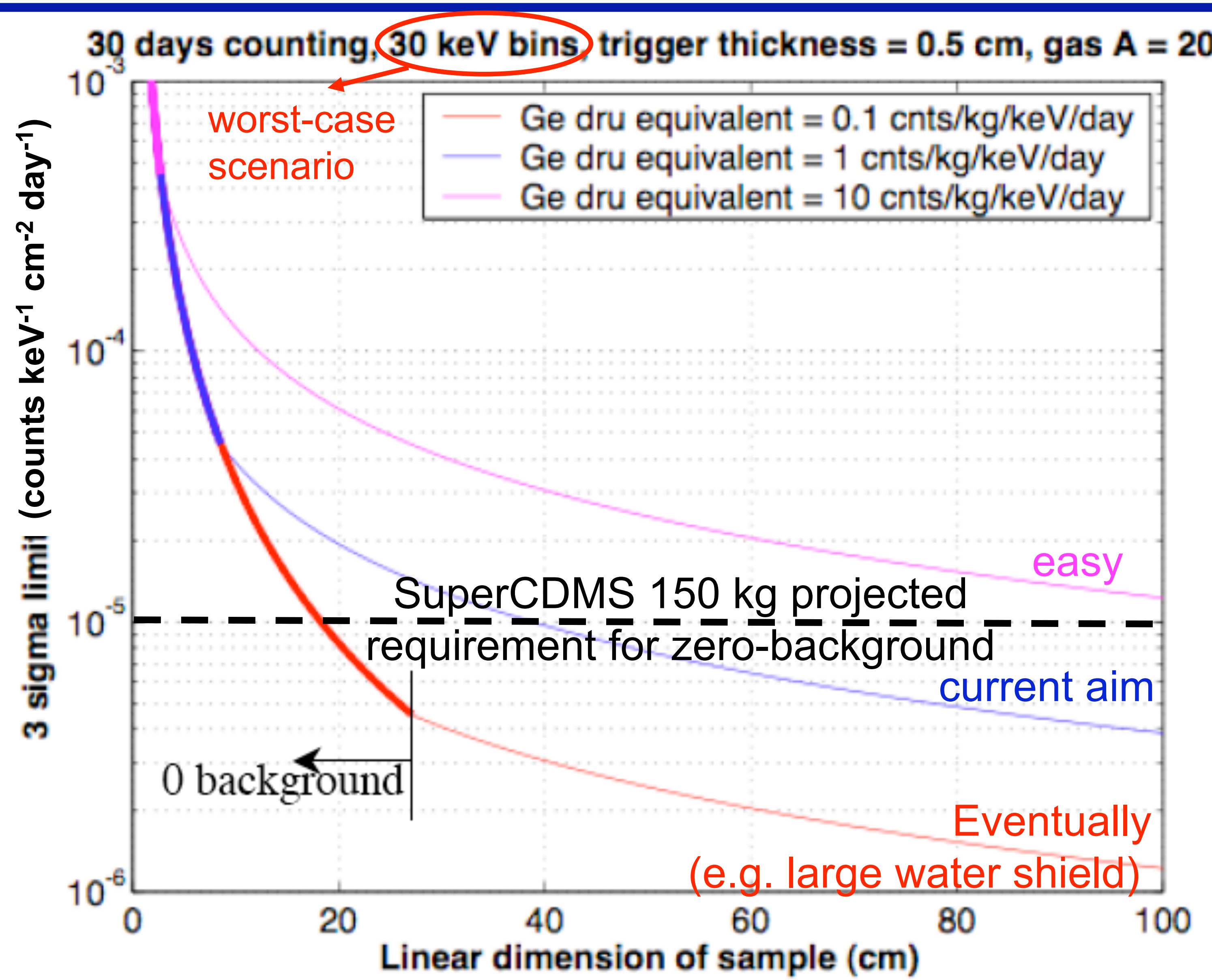
L. DeViveiros & R. Gaitskell, Brown U.



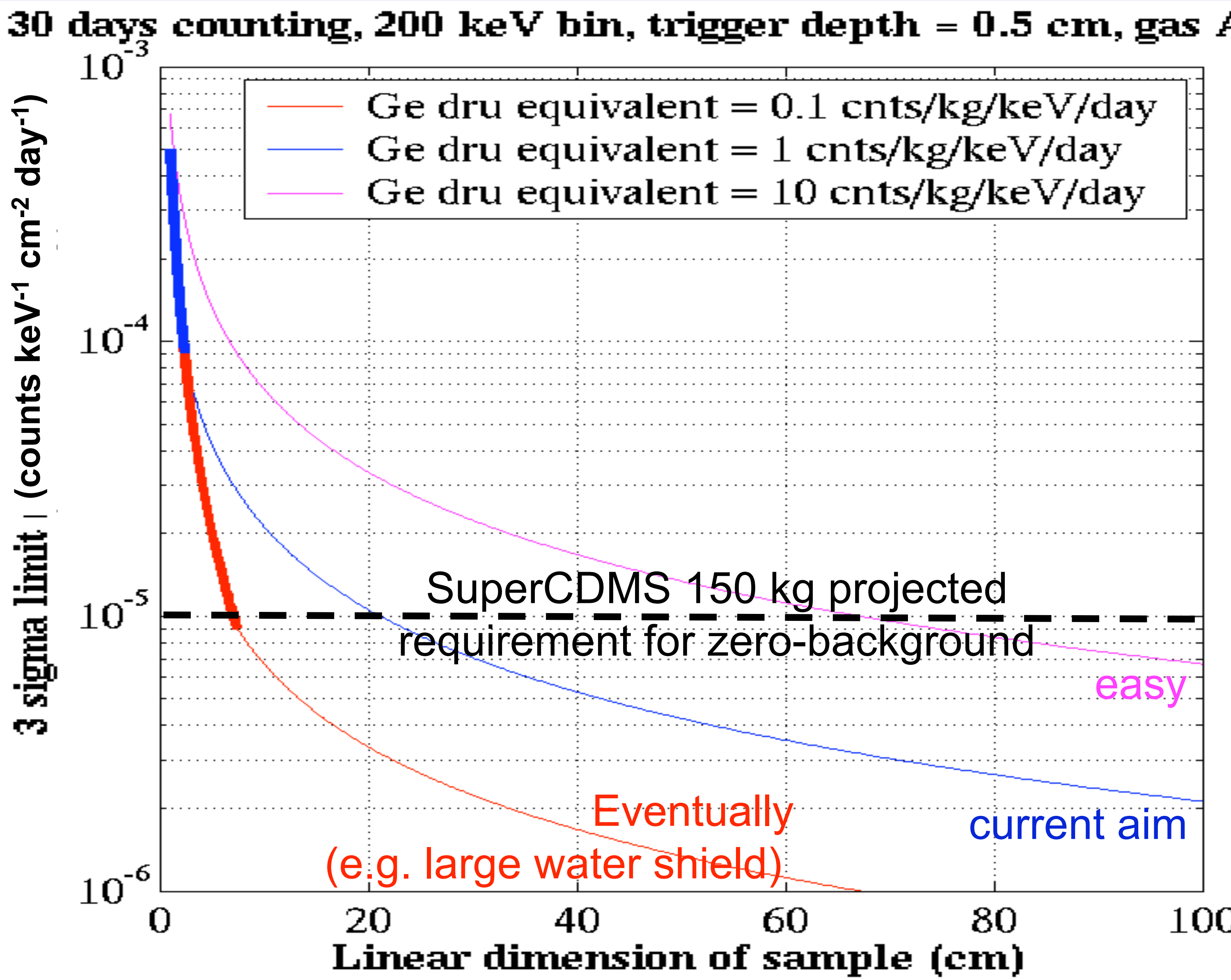
Backgrounds

- Dominated by external gammas (3 x 10^{-5} keV^{-1} cm^{-2} day^{-1})
  - Backgrounds of 1 event/ (kg keV day) straightforward with simple lead shield (including ultraclean copper or ancient lead liner)
  - 10x improvement possible with better shield (e.g. clean water)
- Other:
  - ^{14}C in quench gas (5 x 10^{-6} keV^{-1} cm^{-2} day^{-1})
    - 5% methane, 10^{-16} g/g $^{14}C/^{12}C$
    - Evaluating impact & alternatives (pure gas), may ultimately limit
  - Wires
    - Bulk: negligible (10^{-13} keV^{-1} cm^{-2} day^{-1})
    - Surface: at 25 µm Ø, 0.5 cm spacing -> 200x smaller than sample
      - May have to clean wires (expect 10^{-8} keV^{-1} cm^{-2} day^{-1})
  - Additional Construction: Plastics / Cu (negligible gammas), minimize number of resistors inside chamber (10^{-6} keV^{-1} cm^{-2} day^{-1})
    - Don't need vacuum chamber for neon gas since it can be vented (rather than recovered) after counting

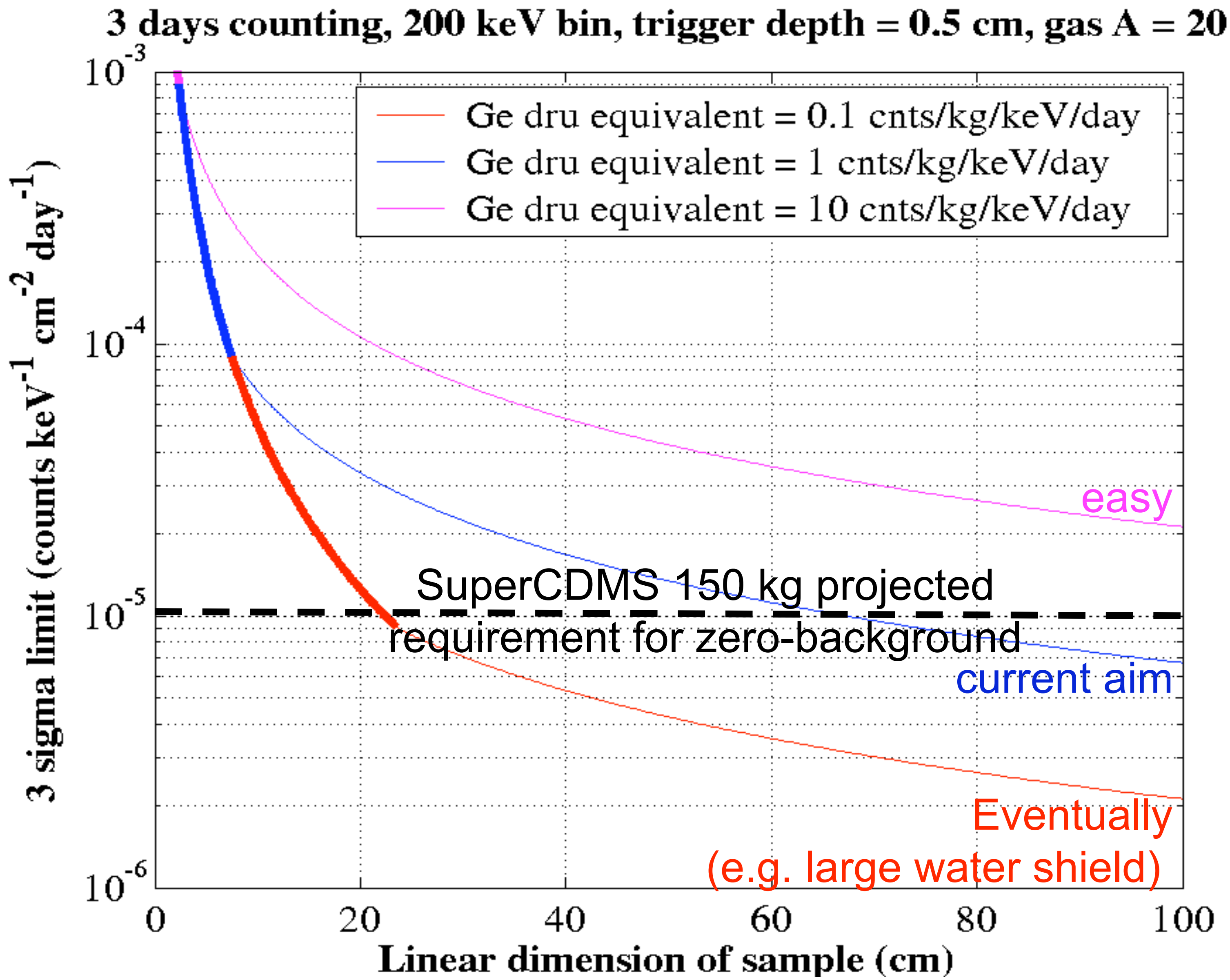
Sensitivity (with background subtraction)



Sensitivity (with background subtraction)

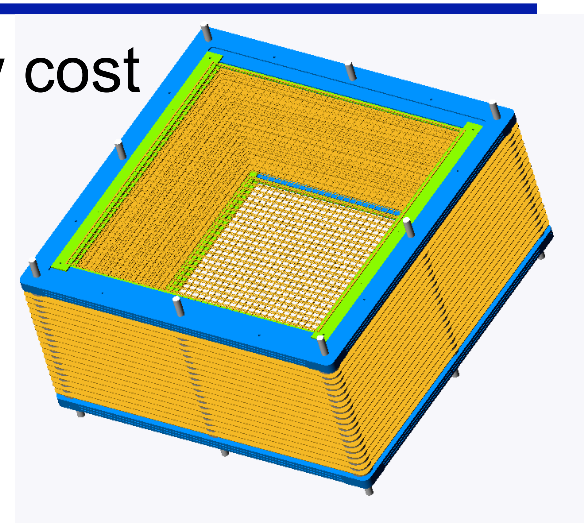


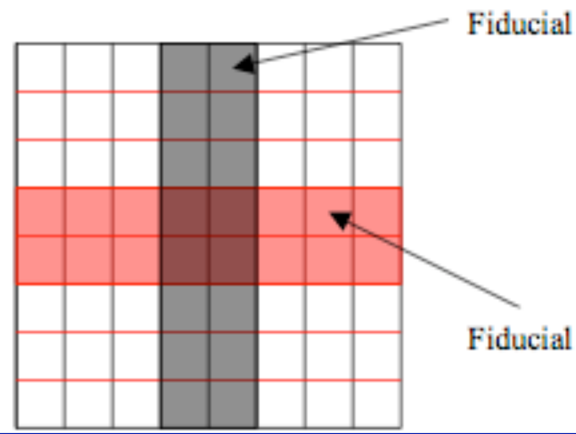
Sensitivity (with background subtraction)



BetaCage Prototype

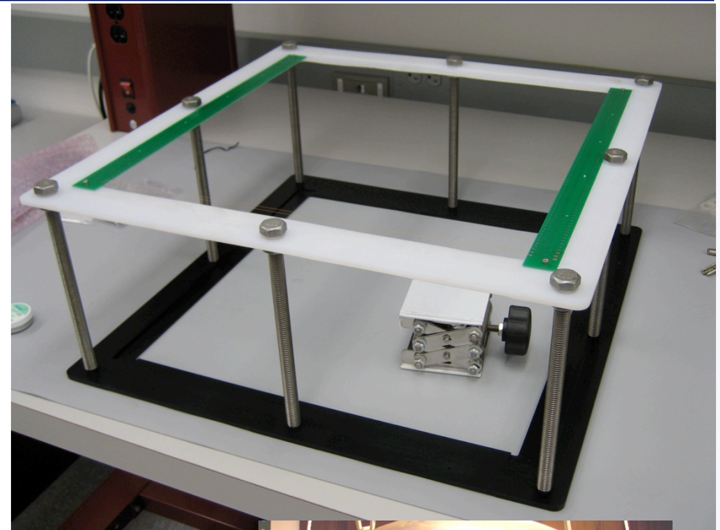
- Purpose: demonstrate functionality at low cost
  - Basic MWPC construction and gas details
  - Beta identification via endpoint energy
  - Alpha identification
  - Some vetoing of gamma-induced events
- Cut costs by not being radiopure, using simplified DAQ, smaller size (40 cm x 40 cm x 20 cm)
  - Aluminum vacuum chamber
  - Start with P10 (argon/methane) not neon
    - Less expensive, simple gas handling
    - Also allows prototype to be half size of final instrument (since electron ranges in Ar are half that in Ne)
  - Use few channels (trigger, bulk, and veto regions

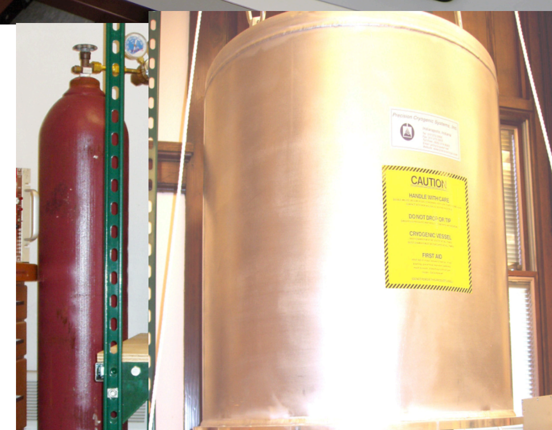




BetaCage Prototype Status

- Bulk of work done by Caltech grad student (Z. Ahmed) and Case undergrad (K. Poinar)
- Mechanical design done
- Electromagnetic simulations done
  - Wiring pad system and wires in hand. Improved frames and field shapers should arrive soon.
  - Test assembly this month at Caltech
- Vacuum chamber made and tested
- HV and gas handling systems done
  - Operation demonstrated using Dahl/Shutt 10-cm prototype-prototype
- DAQ was done (under repair)
- Full assembly at Case Western this summer





(Funded) BetaCage Proposal

- Funded NSF/DOE DUSEL R&D proposal (to start this year)
- Switch to neon from argon, switch to all radiopure materials
  - Switch to neon requires doubling detector size, mix our own gas
  - Plastic chamber
    - Since not vacuum chamber, using Xe would be too expensive
- DAQ
  - Intending to gang together wires as non-redundant mask to reduce channel readout without sacrificing x-y position information
- Shield (1 dru) to be provided by Soudan Low-Background Counting Facility
  - Saves $55k
    - Uses ultra-low-radioactivity Cu as an alternative to ancient Pb
- Possible Upgrades
  - Improved shielding to improve sensitivity

Conclusions

- Funded BetaCage: Large, clean, shielded, underground drift chamber could be world's most sensitive screener for all non-penetrating radiation
- Broad applications in the Hunt for Dark Matter (etc.)
  - Needed for screening CDMS detectors' thin films for beta contaminants
  - Expect virtually no background for alphas
  - Excellent sensitivity for carbon or tritium dating
- Prototype screener to demonstrate operation, energy reconstruction, some background rejection in 2007

Advertisement

I am starting at Syracuse this fall with significant resources and opening for a post-doc